TECHNICAL PROGRESS REPORT 133 OCTOBER 1961

HAWAII AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF HAWAII

Honolulu, Hawaii

# Responses to Phosphate in Coffee

*Bruce J. Cooil,*[1] *Yoshio Watanabe,*[2] *Edward T. Fukunaga,*[3] *and Shigeru Nakata*[4]

Previous experiments involving phosphate fertilization of coffee in the Kona District of Hawaii resulted in the conclusion that little or no phosphate application is needed except to stimulate growth of young trees. Ripperton *et al. (6)* reported growth response to phosphate in young coffee seedlings. However, in an experiment with bearing trees at Kainaliu, application of 160 pounds of nitrogen and 160 pounds of potash per acre annually resulted in yields over a 4-year period essentially the same as those obtained when 160 pounds of phosphate was applied in addition to those rates of nitrogen and potash. Similarly, in 2 experiments performed on farms in the Kona District, Dean and Beaumont *(3)* reported that no statistically significant yield response to phosphate could be demonstrated.

More recent experiments at Kainaliu have shown marked yield responses to supplementary nitrogen applications in summer and fall months *(1, 2)*. In the earlier experiments *(6, 3)*, in which no phosphate response was found,

[1] Dr. Bruce J. Cooil is Plant Physiologist at the Station; Chairman, Department of Plant Physiology, College of Tropical Agriculture; and Professor of Botany, University of Hawaii.

[2] Yoshio Watanabe is Assistant in Plant Physiology at the Station.

[3] Edward T. Fukunaga is Associate Agriculturist and Superintendent, Kona Branch Station.

[4] Shigeru Nakata is Assistant Plant Physiologist at the Station.

fertilizer was applied semi-annually in January or February and in June. Demonstrations of responses to supplementary nitrogen fertilization suggest that in the earlier experiments nitrogen may have been deficient during a part of the year. It seemed possible, therefore, that when the nitrogen requirements of the coffee tree are more fully satisfied by supplementary applications, responses to phosphate fertilization may result. It will be shown below that coffee does respond to phosphate fertilization when the nitrogen is supplied in 4 applications during the year.

## DESCRIPTION OF THE EXPERIMENT

The orchard in which this experiment was performed was described previously *(2)*. The trees had been planted in August 1950, with a spacing of 8½ x 8½ feet. The orchard occupies about 3/4 of an acre. It approaches a rectangular shape with the longest dimension east to west. The trees used constitute a single-row border along the north, east, and west sides of the main experimental plots in the orchard. Previous to initiation of the experiment these trees had been fertilized at the approximate rate of 2,000 pounds of 10–5–20 fertilizer per acre each year. This fertilizer had been applied in semi-annual applications in March and June each year. In June 1957, fertilizer treatments were begun as shown in table 1. Sixty trees in the border were assigned to 6 replicate blocks, each containing 10 trees. A plot of 5 trees within each block received each treatment. Three of the blocks were on the north side of the orchard, 1 on the east end, 1 on the west end, and 1 partially on the north side and partially on the west end. One of the treatments within the orchard had a fertilizer regime identical to that of the low phosphate

TABLE 1. Fertilizer schedule from June 1957 through October 1960

| Month applied | Low phosphate plots: Fertilizer formula | Low phosphate plots: Pounds per acre | Extra phosphate plots: Fertilizer formula | Extra phosphate plots: Pounds per acre |
|---|---|---|---|---|
| February | 10–5–20 | 900 | 10– 5–20 | 900 |
| June | 10–5–20 | 900 | 10– 5–20 | 900 |
| August | 21–0– 0 | 428 | 21–53– 0 | 428 |
| October | 21–0– 0 | 428 | 21–53– 0 | 428 |

treatment in the border row. This treatment was represented by a 4-tree plot in each of 6 randomized blocks, and provided a check for evaluating any border effect at the low phosphate level.

## METHODS

Beginning in January 1958, leaves were sampled monthly by procedures described previously (2) except that each sample from the border row consisted of 1 leaf from each tree receiving the same treatment. Total nitrogen in the leaf samples was determined by the Kjeldahl method modified to include nitrogen of nitrates (5). Total nitrogen was expressed as percentage of the starch-free dry matter after estimating starch as described previously (2). Total phosphorus was determined by the procedure of Hitson and Mellon (4) after ashing in a muffle furnace at 475° to 500° C. for 16 hours.

## EXPERIMENTAL RESULTS AND DISCUSSION

Coffee yields for the 4 crops harvested since initiation of the experiment are shown in table 2. Comparisons of low phosphate trees within the orchard to trees in the border reveal virtually identical yields for the last 3 years. It appears there is no border effect on yield under the conditions of this experiment, at least at the low phosphate level.

TABLE 2. Yields and yield responses to extra phosphate

| Crop year | Yield (cwt. cherry per acre): Low phosphate, Within orchard | Low phosphate, Border | Extra phosphate border | Least significant difference (border plots): .05 | .01 | Response to extra phosphate (border plots): Cwt. cherry per acre | % |
|---|---|---|---|---|---|---|---|
| 1957–58 | 193 | 174 | 202 | 41.1 | 64.5 | 28 | 16.1 |
| 1958–59 | 140 | 142 | 171 | 31.0 | 48.6 | 29 | 20.4 |
| 1959–60 | 150 | 143 | 186 | 35.8 | 56.2 | 43* | 30.1 |
| 1960–61 | 218 | 220 | 288 | 14.1 | 22.2 | 68** | 30.9 |
| Mean: last 3 years | 169 | 168 | 215 | 15.1 | 23.7 | 47** | 28.0 |

*Difference exceeds that at p = .05

**Difference exceeds that at p = .01

The difference between treatments in the 1957–58 crop was much less than that required for statistical significance. This is to be expected, as differential phosphate applications were begun in August 1957 at a time when the 1957–58 crop was maturing. In the 1958–59 crop the phosphate response approached that required for significance at the 5 percent level. The 1959–60 response to phosphate well exceeded the 5 percent level, and in 1960–61 the phosphate response greatly exceeded that required for significance at the 1 percent level. Mean yields for the 3 crops beginning with that of 1958–59 showed a highly significant response to extra phosphate.

The lower percentage response to phosphate in the 1958–59 crop (20.4 percent) than in the 2 subsequent years suggests that full response to phosphate fertilization is realized only 2 full years after phosphate application is begun. It is evident, however, that the results of this experiment do not answer the question of how much phosphate should be applied annually. It is anticipated that another experiment now in progress will provide answers to this question.

The percentage response to extra phosphate was nearly the same in the 1959–60 crop (30.1 percent) as it was in the 1960–61 crop (30.9 percent) despite the fact that 1959 was a year of relatively low bearing and 1960 was one of high yields. These results suggest that in terms of percentage response phosphate acts independently of the environmental and internal factors responsible for large fluctuations in yields between years.

Total phosphorus concentrations in the leaves sampled are shown in table 3. Within each treatment considerable variations in phosphorus values were found during each year. There were also differences associated with the year of sampling. Leaf phosphorus concentrations did not respond consistently to extra phosphate application in 1958. Major responses to extra phosphate application were found in the months of February, March, and April, particularly in 1959 and 1960. Perhaps it is noteworthy that these months represent the periods of major flowering and initiation of vegetative growth.

When comparisons are made between phosphorus values for the same season in different years, the greatest differences are found again in the February to April season. For each treatment, leaves sampled during the February to April period of 1959 were higher in phosphorus than those sampled during the same season of 1958 or 1960.

If leaf phosphorus is in some way related to yield, it appears that it is the February to April phosphorus in the year preceding that of the yield which is involved. Hence, the highest phosphorus values were found in March 1959, and the highest yield was for the 1960–61 crop. This suggests that the primary response to phosphate is in stimulating and maintaining growth of lateral branches which will serve as bearing surface the following year.

TABLE 3. Total phosphorus concentrations in leaf samples (percentage of the dry weight)

| Month sampled | Low phosphate | | Extra phosphate | Low phosphate | | Extra phosphate | Low phosphate | | Extra phosphate |
|---|---|---|---|---|---|---|---|---|---|
| | Within orchard | Border | Border | Within orchard | Border | Border | Within orchard | Border | Border |
| | Leaves formed during the calendar year previous to the year sampled (number 3 leaves) | | | | | | | | |
| January | .083 | .094 | .103 | .076 | .111 | .115 | .092 | .102 | .104 |
| February | .091 | .102 | .102 | .121 | .123 | .132 | .107 | .109 | .129 |
| March | .112 | .106 | .110 | .126 | .129 | .154 | .103 | .103 | .112 |
| April | .114 | .103 | .112 | .128 | .125 | .135 | .101 | .094 | .108 |
| May | .102 | .088 | .095 | .113 | .109 | .107 | .090 | .077 | .090 |
| June | .085 | .081 | .090 | .094 | .076 | .091 | .074 | .067 | .083 |
| July | .089 | .078 | .084 | .088 | .078 | .082 | .078 | .063 | .074 |
| August | .092 | .078 | .087 | .082 | .071 | .084 | – | .079 | .080 |
| September | .084 | .073 | .080 | .082 | .068 | .081 | – | .069 | .073 |
| October | .078 | .070 | .071 | .068 | .071 | .068 | – | .065 | .067 |
| November | .081 | .070 | .073 | .071 | .074 | .078 | – | .065 | .067 |
| December | .071 | .068 | .074 | .073 | .065 | .086 | – | .058 | .069 |

*(Continued)*

TABLE 3. Total phosphorus concentrations in leaf samples (percentage of the dry weight)
*(Continued)*

| Month sampled | Low phosphate |  | Extra phosphate | Low phosphate |  | Extra phosphate | Low phosphate |  | Extra phosphate |
|---|---|---|---|---|---|---|---|---|---|
|  | Within orchard | Border | Border | Within orchard | Border | Border | Within orchard | Border | Border |
| Leaves formed during the calendar year sampled (number 2 leaves) |  |  |  |  |  |  |  |  |  |
| May | .131 | .123 | .135 | .131 | .135 | .131 | .111 | .107 | .119 |
| June | .116 | .116 | .124 | .130 | .121 | .124 | .112 | .102 | .116 |
| July | .119 | .111 | .124 | .123 | .119 | .123 | .111 | .103 | .113 |
| August | .120 | .118 | .124 | .120 | .111 | .123 | .106 | .115 | .123 |
| September | .112 | .110 | .109 | .115 | .115 | .121 | – | .102 | .111 |
| October | .106 | .115 | .112 | .103 | .106 | .115 | – | .103 | .099 |
| November | .101 | .103 | .112 | .108 | .109 | .113 | – | .091 | .099 |
| December | .094 | .103 | .111 | .098 | .096 | .106 | – | .084 | .089 |

Although the same quantities of nitrogen were applied in the 2 phosphate treatments, there might be some possibility of difference in behavior between the ammonium sulfate and ammonium phosphate salts in the soil-plant complex. To examine this possibility, total nitrogen determinations were made for the months representing the main flowering season each year. This is the season when leaf nitrogen is best correlated with yield (2). The leaf nitrogen values (table 4) for the 2 phosphate treatments are generally very similar.

TABLE 4. Nitrogen concentration in leaf samples (percentage of starch-free dry matter)

| Month sampled | 1958 Low phosphate | 1958 Extra phosphate | 1959 Low phosphate | 1959 Extra phosphate | 1960 Low phosphate | 1960 Extra phosphate |
|---|---|---|---|---|---|---|
| January | 2.77 | 2.79 | 2.84 | 2.85 | 2.26 | 2.61 |
| February | 2.90 | 2.72 | 2.81 | 2.75 | 2.73 | 2.77 |
| March | 2.96 | 3.02 | 2.85 | 2.94 | 2.83 | 2.86 |
| April | 3.17 | 3.05 | 2.83 | 2.72 | 2.69 | 2.68 |
| May | 3.07 | 2.77 | 2.58 | 2.53 | 2.51 | 2.47 |
| June | 2.52 | 2.48 | 2.30 | 2.30 | 2.28 | 2.22 |

## SUMMARY

Comparisons were made between coffee trees which received low phosphate and extra phosphate treatments over a period of 3 years. Nitrogen fertilizer was supplied in 4 applications each year in each treatment. Yield increases resulting from the extra phosphate were 20.4 percent, 30.1 percent, and 30.9 percent, respectively, for crops harvested 1, 2, and 3 years after beginning the treatments.

Leaf phosphorus concentrations varied with seasons and years, but were generally higher in the extra phosphate treatment after the first year. The highest phosphorus values and the most consistent differences in phosphate concentration between treatments were found during the February to April period in the second and third years of treatment. The highest leaf phosphorus values were found in the second year of treatment, whereas the highest yields were in the third year.

The phosphate treatments employed had little or no influence on leaf nitrogen values.

## LITERATURE CITED


1. Beaumont, J. H., and E. T. Fukunaga. 1958. Factors affecting growth and yield of coffee in Kona, Hawaii. Hawaii Agr. Expt. Sta. Bul. 113.

2. Cooil, B. J., E. T. Fukunaga, and M. Awada. 1958. Fertilization of coffee in Kona with special reference to nitrogen nutrition. Hawaii Agr. Expt. Sta. Progress Notes 117.

3. Dean, L. A., and J. H. Beaumont. 1938. Soils and fertilizers in relation to the yield, growth and composition of the coffee tree. Proc. Amer. Soc. Hort. Sci. 36: 28–35.

4. Hitson, R. E., and M. G. Mellon. 1944. Colorimetric determination of phosphorus as molybdivanado-phosphoric acid. Ind. and Eng. Chem., Anal. Ed. 16: 379–383.

5. Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists. 1945. 6th Edition. Washington.

6. Ripperton, J. C., Y. B. Goto, and R. K. Pahau. 1935. Coffee cultural practices in the Kona District of Hawaii. Hawaii Agr. Expt. Sta. Bul. 75.


1862-1962
LAND GRANT COLLEGES
CENTENNIAL OF THE MORRILL ACT OF 1862
CREATING THE LAND-GRANT COLLEGE SYSTEM


**UNIVERSITY OF HAWAII**
**COLLEGE OF TROPICAL AGRICULTURE**
**HAWAII AGRICULTURAL EXPERIMENT STATION**
**HONOLULU, HAWAII**

---

**LAURENCE H. SNYDER**
**President of the University**

**MORTON M. ROSENBERG**
**Dean of the College and**
**Director of the Experiment Station**